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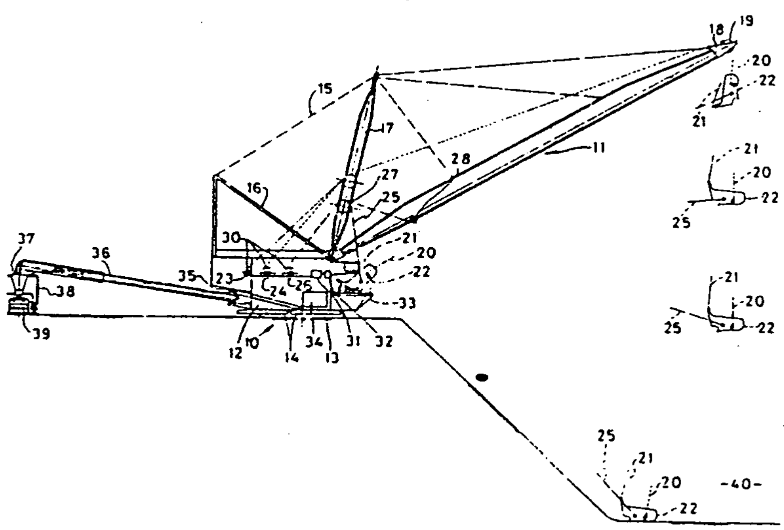

(57) Abstract

Excavation apparatus (10) having a rope controlled bucket (22) supported [illegible] he st[illegible]pe (20) and a drag rope (25) and having a receptacle (33) into which the contents of the bucket (22) may be tipped [illegible] crushing and conveying to a location remote from the excavation apparatus (10). The bucket (22) is supported so that its rotational attitude as well as its position may be monitored and controlled to permit accurate tipping of the bucket (22) into the receptacle (33).

EXCAVATION APPARATUS

This invention relates to improvements in and relating to excavation apparatus and to methods of operating same.

In particular this invention relates to the excavation of earth such as overburden from deposits to be mined although it is not limited to such applications. However for the purpose of illustrating the present invention reference will be made hereinafter to its application to removing overburden from coal seams in open cut mining of coal.

The normal technique employed in open cut mining is strip mining, in which overburden is removed from the coal in successive strips and placed on top of an adjacent strip from which the coal has been mined. The coal seam is generally inclined to the ground surface and mining commences along the shallow edge of the seam. As the mining progresses across the downwardly inclined seam more overburden has to be removed and the adjacent mined strip may not accommodate all the excavated overburden.

Overburden stripping is normally carried out using large walking draglines. In such machines a bucket is suspended from a boom supported on a rotatable house and a winch cable connects the bucket to the house to enable it to be dragged towards the house to scoop up the overburden. The house is supported for rotation about a vertical axis whereby the boom may be swung sideways to enable the bucket to be emptied at either side of the strip being excavated. The length of the dragline boom determines the dumping radius and in operation the overburden is dumped in a series of spoil piles each centered at the dumping radius. Each spoil pile may be built up until the toe of the pile is adjacent the bottom of the pit being excavated. Extra overburden cannot be tipped onto the spoil pile as it would spill back onto the excavation. Accordingly the excess overburden has to be transported elsewhere for dumping. This extra handling operation adds markedly to the cost of excavation. In practice at overburden depths of forty-five metres or more, large walking draglines must rehandle overburden so many times

that such operations become uneconomical.

Accordingly, when the pit depth exceeds a selected depth, such as forty-five metres mentioned above, other types of excavating means are first used to reduce the depth of overburden prior to using the dragline. The extent of re-handling has a major effect of both productivity and economics of overburden removal. If all prime overburden is rehandled once (a rehandle factor of 100%), the productivity is halved and the cost per cubic metre of prime overburden is doubled compared to direct spoiling.

In order to avoid this expensive rehandling operation preliminary excavation is carried out by the use of scrapers, trucks and shovels or by bucket-wheel excavators to provide a working grade along which the dragline works such that the coal seam or bottom of pit being excavated does not exceed a depth of about thirty five metres below the working grade. This operation is called benching. This pre-stripping or benching process has a higher cost of removal per cubic metre of prime overburden than a dragline but it entails no re-handling costs and is thus economical.

At present the most economical method of benching utilizes a bucket-wheel excavator coupled to a system of conveyor belts which convey the spoil to spreading apparatus which distributes the spoil to a desired location such as between previously formed rows of spoil piles in order to reduce subsequent levelling and reclamation costs. This system has a basic handling capacity similar to that of a dragline but may cost twice as much, so that it is economical only when the rehandle factor for the dragline rises above 100%. It also has the disadvantage that its capacity is greatly reduced when digging hard overburden such as rock.

Overburden removal costs also depend on the efficiency of operation of the dragline. At present each excavation cycle includes hoisting the bucket; lowering the bucket onto the overburden; hauling the bucket towards the house to dig the overburden; returning the bucket to the outer boom end; swinging the boom to position the bucket over a spoil pile at the side of the pit being excavated; emptying the bucket and

returning the boom into position for the next cycle. Because of the number of separate operations required per cycle, the total cycle time is relatively long compared with the actual digging time.

In the presently available draglines, the bucket is suspended from the boom point by a hoist rope and is connected to the winching equipment in the dragline house by a drag rope which is utilized to haul the bucket towards the house to perform its digging operation. A stabilizing rope passes from the drag rope about a pulley on the hoist rope for return to the bucket. This rope maintains the operative digging orientation of the bucket during digging and hositing operations. When tension is released from the drag rope this stabilizing rope becomes inoperative and the bucket tips. Data logging equipment is frequently utilized to provide an indication of the position of the bucket to assist operators in the manual control of the bucket so that operational efficiency may be maximised. Manual operation however, while relatively inefficient for repetitive operations is still utilized since the present cycle times are relatively long and operational accuracy is not critical.

This invention aims to alleviate the disadvantages associated with the presently available excavation apparatus and to provide excavation apparatus and a method of operating same which will be reliable and efficient in use. Other objects and advantages of this invention will hereinafter become apparent.

With the foregoing and other objects in view, this invention resides in one aspect in excavation apparatus having a bucket controlled for movement by ropes including a boom-supported hoist rope and a drag rope; drive means for actuating said ropes, monitoring means for monitoring the position and rotational orientation of the bucket relative to said boom and computing means for scanning input information from said monitoring means and operable to compute the position and orientation of said bucket. Preferably the computing means

is programmable and adapted to actuate said drive means in accordance with a programmed sequence of bucket positions. Alternatively the computing means may provide a visual indication of the bucket position to enable an operator to actuate the drive means at the appropriate times.

The position of the bucket may be monitored by monitoring parameters such as the operative lengths and/or tension of hoist and drag ropes, information on boom swing speed and torque and data on the fleet angles of the boom point sheaves and fairleads. Such information would enable the longitudinal and the lateral position of the bucket to be determined relative to the boom.

Preferably the ropes controlling the bucket movement include a third rope additional to said hoist rope and said drag rope whereby the relative operative lengths and/or tensions of the ropes may be monitored to provide input information for computing the rotational orientation of the bucket. Preferably the monitoring signals are induced from electrical signals but of course they could be optical or pneumatic signals or the like as desired. Furthermore transducers may be provided on the rope drums to calculate the length of the respective ropes deployed at any instant. From this date the computing means could utilize co-ordinate geometry to compute the position of the bucket.

Preferably the computing means is programmed to actuate the drive means to tip the bucket at a selected position so as to achieve accurate tipping at a selected position. This may be remote from the dragline operator or adjacent as desired. Such accurate tipping is not possible at present since the operator has little control over the lateral position of the bucket relative to the boom which varies as the bucket swings out of the vertical plane passing through the boom axis when the machine rotates.

In another aspect this invention resides broadly in excavation apparatus having a boom-supported bucket adapted for actuation by ropes including a hoist rope supported by the boom and a drag rope; drive means for actuating said ropes,

monitoring means for monitoring the position of the bucket relative to said boom; computing means adapted to scan input information from said monitoring means to compute the position of said bucket and said computing means being programmable to actuate said drive means to perform a programmed sequence of bucket operations.

In a further aspect this invention resides broadly in a method of excavation using excavation apparatus of the type defined above, and suitably in the form of a dragline and including gathering material into the bucket, tipping the recovered material from the bucket into a receptacle and conveying the recovered material to a selected position for distribution. The receptacle may be mounted remote from the dragline but preferably it is mounted on or adjacent the dragline whereby emptying of the bucket may be carried out at the end of the drag operation and prior to return of the bucket for the next excavating process. It is also preferred that the recovered material be crushed prior to being conveyed to the selected location.

In accordance with a further aspect this invention resides broadly in excavation apparatus, having a boom-supported bucket adapted for actuation by ropes including a hoist rope supported by the boom and a drag rope for moving the bucket in a longitudinal direction relative to the boom; drive means for actuating said ropes, monitoring means for monitoring the position of the bucket relative to said boom; computing means adapted to scan input information from said monitoring means to compute the position of said bucket whereby said drive means may be manipulated in accordance with selected bucket positions; a receptacle on or adjacent the dragline and crushing means to crush recovered material deposited from said bucket into said receptacle. Preferably the receptacle is mounted on the dragline house beneath the bucket supporting boom and said control means is adapted to be manipulated to tip the bucket contents into said receptacle.

In order that the bucket may be emptied into said receptacle this invention in a further aspect provides a

method of supporting a bucket by a plurality of ropes the operative relative lengths of which may be independantly varied for controlling the rotational position of said bucket about a tipping axis. Preferably the bucket tipping axis extends transverse to the boom or in any selected direction. Preferably the operative lengths of said plurality of ropes are monitored by said monitoring means and fed to programmable computing means whereby the operation of said bucket may be automatically controlled to dig and empty recovered material.

In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention, wherein:-

Fig 1 is a perspective view of a dragline assembly made in accordance with the present invention;

Fig 2 is a diagramatic side view of the dragline assembly illustrating the bucket tipping action, and

Fig 3 is a diagramatic plan view illustrating a typical conveyor arrangement for distributing over-burden.

As illustrated the dragline assembly 10 includes a bucket-supporting boom 11 pivotally connected to a control house 12 which is rotatably mounted on a support tub 13. Walking feet 14 are provided in known manner to enable the dragline assembly 10 to move from location to location. The boom 11 is supported by cables 15 extending from a fixed A-frame 16 at the rear of the house 12 and across a pivotable mast 17 to the boom point 18. Sheaves 19 are located at this point 18 for hoist and dump ropes 20 and 21 which connect to the bucket 22 and which return to respective winching drums 23 and 24 in the house 12. A drag rope 25 extends from the bucket 22 to a third winch drum 26 mounted in the house 12. The drag rope 25 passes across a return idler sheave 27 supported on the mast and beneath a deflecting idler sheave 28 on the boom 11.

It will be seen that the three ropes 20, 21 and 25

support the elevated bucket 22 at all times such that both the path of the bucket and its rotational attitude with respect to a laterally extending axis may be controlled by varying the relative lengths and/or tensions of the ropes. For this purpose transducers 30 are provided on the rope drums 23, 24 and 26 to monitor the length of the respective ropes extending from the drums to the bucket. From this data, a built in computer 31 utilizes co-ordinate geometry to compute the position of the bucket 22 and its rotational condition. The computer is coupled to drive means 32 for the drums 23, 24 and 26 and is also able to predict future movement of the bucket by calculations based on ballastic mathematics. Thus at any time the computer is able to detect the possibility of the bucket contacting the machine and can actuate the drive means 32 to alter the rope tensions to prevent this.

The computer 31 may be programmed to control the rope drums 23, 24 and 26 for the process of hauling in the bucket 22, dumping its contents into a hopper 33 supported on the house 12 beneath the base of the boom 11 and removing the bucket 22 from the immediate area of the hoppers 33. In normal operation of the dragline, an operator on completing a drag cycle engages an automatic dump control to initiate computer control of the operation. The computer would then control actuation of the rope drums to haul the full bucket in along an optimum path, decelerate it, dump it, and return it to the excavation.

Material from the hopper 33 is fed to a large capacity crusher 34 supported in the house 12. The crushed material is fed from the crusher 34 via an apron conveyor 35 for discharge onto a telescopic conveyor assembly 36 which transfers the material to a hopper 37 on a belt wagon 38 straddling a yard belt conveyor 39 extending alongside the excavated pit 40. Suitably the material in an open cut mining operation is then conveyed across the pit by an elevating belt conveyor 41 onto a further longitudinal conveyor 42 from which it may be spread by a tripper/spreader assembly 43. The latter is movable along the conveyor 42 to cause discharge

of material at any position therealong, for example between the spoil piles 44.

It will be seen from the drawings that the connections between the ropes 20, 21 and 25 and the bucket 22 are so arranged that when the bucket is supported adjacent the boom point 18, its weight is taken by the hoist and dump ropes 20 and 21. The hoist rope 20 is positioned adjacent the centre of gravity of the bucket 22 so that it takes a major proportion of the weight of the bucket. The drag rope 25 is connected to the bucket 22 rearwardly of its centre of gravity and it is arranged for retraction towards the sheave 27 which is disposed directly above the hopper 33. In use, as the bucket 22 is hauled towards the sheave its weight is transferred to the drag rope until at the inner limit of its travel it is largely supported by the drag rope 25 and partly by the upwardly inclined hoist and dump ropes 20 and 21. When the bucket is immediately above the hopper 33 it is positioned for tipping. Tipping of the bucket during passage to its inner limit is prevented by maintaining tension in the dump rope 21. As soon as this rope 21 is released the bucket will begin to rotate forwardly to enable the contents to spill into the hopper 33. Emptying of the bucket 22 may be assisted by suitable automatic manipulation of the ropes such as by momentarily releasing the drag rope 25 and quickly retracting the hoist rope 20. Tipping or emptying of the bucket 22 is a continuous action controlled by the on-board computer to utilize the momentum of the bucket and contents together with external forces applied by the ropes to cause efficient emptying without substantially interrupting the drag and return cycle of the bucket. During this process the computer 31 would continue at all times to carry out its calculations to ensure that no contact occurs between the bucket and the machine.

From the above it will be seen that a dragline made in accordance with one aspect of this invention has a digging and dumping cycle which utilizes a minimum of hoisting and no swinging of the boom. Thus cycle times will be greatly

reduced compared to conventional dragline machines. Cycle times in some instances may be reduced by one half. In addition to the resultant increase in productivity no re-handling of excavated material is required. Thus large economies of operation may be effected.

In a further embodiment, the invention is applied to convert an existing dragline whereby it may be controlled to dump the bucket contents into a free standing hopper or the like at one side of the pit being excavated. In this embodiment a computing means is connected to monitoring means on the dragline adapted to monitor variables such as the length of hoist and drag ropes deployed, information on boom swing speed and torque and data on the fleet angles of the boom point sheaves and fairleads so as to enable the out of plane position of the bucket relative to the boom to be measured and future motion of the bucket predicted. Thus once the computing means has been supplied with the position of the hopper or receptacle relative to the dragline, it could take control of the dragline directly after filling the bucket to adjust rope lengths and swing the machine to position the bucket relative to the hopper to ensure that the contents are tipped into the hopper.

Such a system would remove the problem of total manual control and rehandling of the excavated material and consequently it would improve efficiency when operating in deep overburden.

It will be noted that reference herein has been made to ropes for controlling the movement of the bucket. In each instance in the specification and claims a reference to a rope is to embrace a reference to a rope group or a reference to a cable or a cable set as desired. Also where mention is made to drive means for actuating the ropes it is to be understood that this includes a reference to moving the rope in either direction such as by winding or unwinding a rope onto or from a drum or the like.

It will of course be realised that the above has been given by way of illustrative example only of the invention

and that all such modifications and variations thereto as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of this invention as is defined in the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. Excavation apparatus having a bucket controlled for movement by ropes including a boom-supported hoist rope and a drag rope; drive means for actuating said ropes, monitoring means for monitoring the position and rotational orientation of the bucket relative to said boom and computing means for scanning input information from said monitoring means and operable to compute the position and orientation of said bucket.

2. Excavation apparatus accordingly to claim 1, wherein said ropes include a third rope whereby the relative operative lengths and/or tension of said hoist and drag ropes and said third rope may be monitored to provide input information for computing the rotational orientation of the bucket.

3. Excavation apparatus according to any one of the preceding claims, wherein there is provided a receptacle for receiving material tipped from said bucket and conveying means for conveying said material from said receptacle to a selected remote location.

4. Excavation apparatus according to claim 3, wherein said receptacle is mounted on the excavation apparatus and wherein there is further provided a crusher on said excavation apparatus for crushing material tipped into said receptacle and discharge means for transporting crushed material to a discharge station.

5. Excavation apparatus according to claim 4, wherein said drag rope passes to said bucket from guide means disposed above said receptacle.

6. Excavation apparatus according to claim 4 or claim 5, wherein said hoist and third ropes pass to said bucket from the outer end of said boom.

7. Excavation apparatus according to any one of the preceding claims, wherein said computing means is programmable and is operatively connected to said drive means for actuating the drive means to perform a programmed sequence of bucket operations.

8. Excavation apparatus having a boom-supported bucket adapted for actuation by ropes including a hoist rope supported by the boom and a drag rope; drive means for actuating said ropes; monitoring means for monitoring the position of the bucket relative to said boom; computing means adapted to scan input information from said monitoring means to compute the position of said bucket, and said computing means being programmable to actuate said drive means to perform a programmed sequence of bucket operations.

9. Excavation apparatus according to claim 8, wherein said monitoring means monitors information determining both lateral and longitudinal positions of the bucket relative to said boom whereby said computing means may determine both said lateral and longitudinal positions of the bucket.

10. Excavation apparatus according to Claim 9 or claim 8, wherein said ropes include a third rope whereby the relative operative lengths and/or tensions of said hoist and drag ropes and said third rope may be monitored to provide input information for computing the rotational orientation of the bucket.

11. Excavation apparatus according to any one of claims 8 to 10 wherein said monitoring means monitors the operative lengths and/or tensions of said ropes, information on the boom swing speed and/or swing torque applied to the boom and the fleet angle of a sheave or sheaves about which ropes pass to said bucket.

12. Excavation apparatus having a bucket controlled for movement by ropes including a boom-supported hoist rope and a drag rope; drive means for actuating said ropes; a receptacle on said apparatus for receiving material tipped from said bucket and said drag rope passing to said bucket from guide means disposed above said receptacle.

13. A method of excavating using drag line apparatus, including gathering material into the bucket, tipping the recovered material from the bucket into a receptacle and conveying the recovered material to a selected position for distribution.

14. A method of excavating according to claim 13, including tipping the bucket at the end of the drag operation prior to returning the bucket towards the boom point for the following drag operation.

15. A method of excavating according to claim 14 and wherein the receptacle is mounted on the excavation apparatus, the method further including crushing the material from said receptacle prior to discharging the material for distribution.

16. A method of excavating according to claim 15, including depositing crushed material onto a conveyor belt adapted to transfer the material away from the excavation apparatus for discharge at a remote location.

17. A method accordingly to any one of claims 13 to 16, wherein said drag line apparatus is as defined in any one of claims 1 to 12.

18. A method substantially as hereinbefore described with reference to the accompanying drawings.

19. Excavation apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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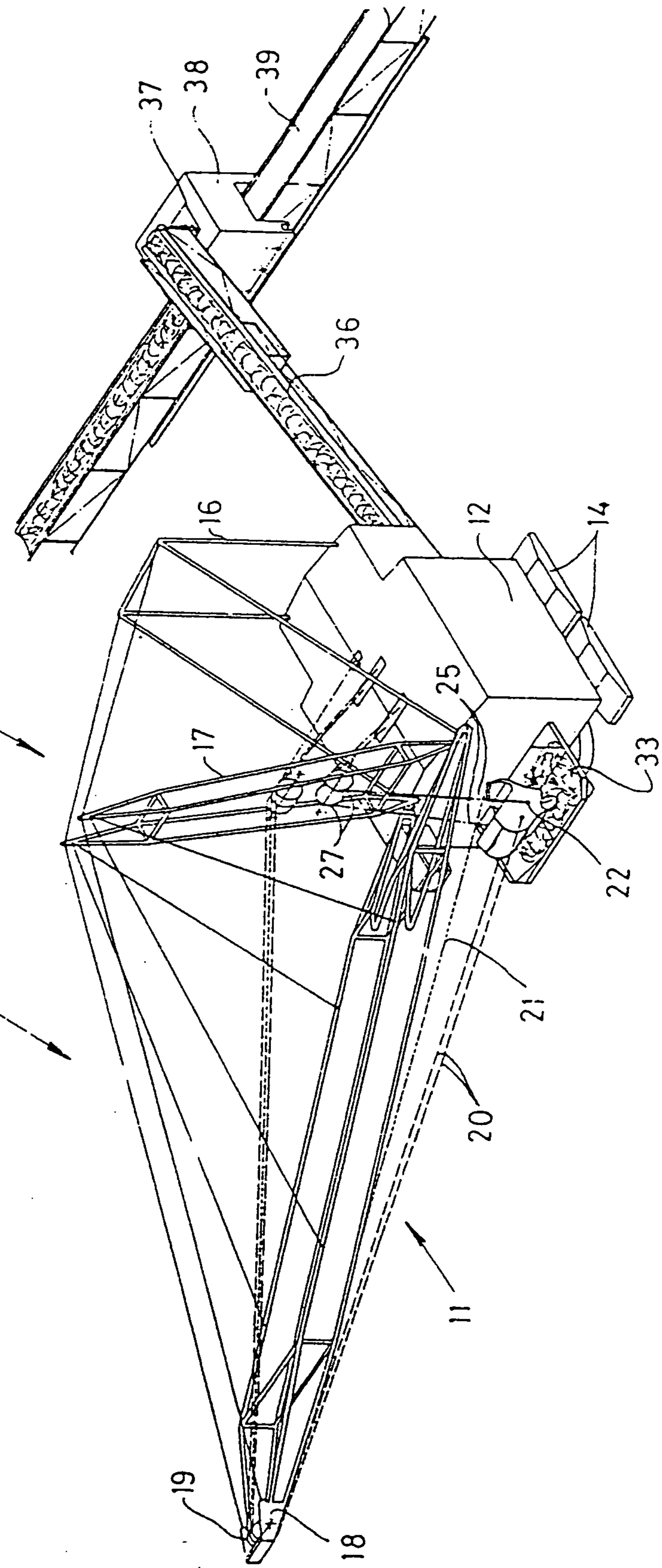

Fig. 1.

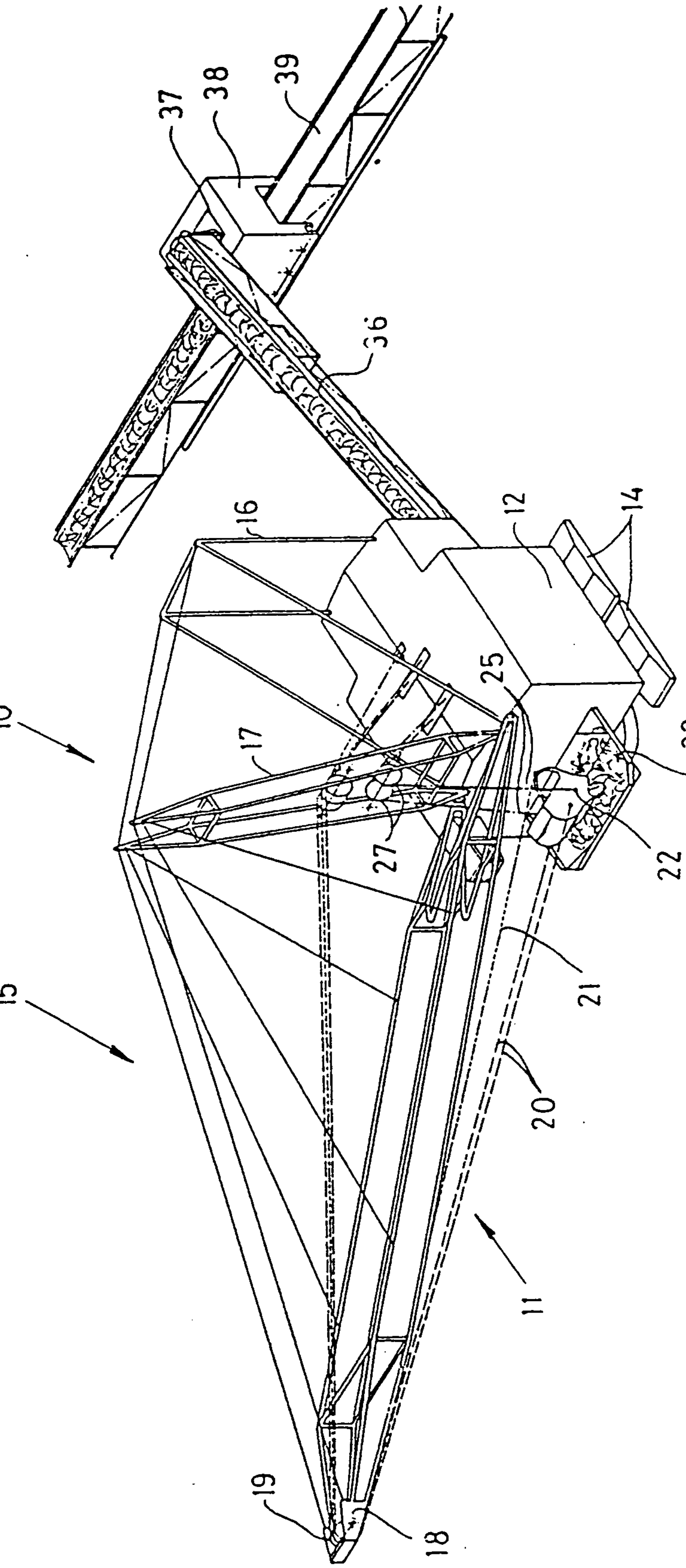

Fig. 1

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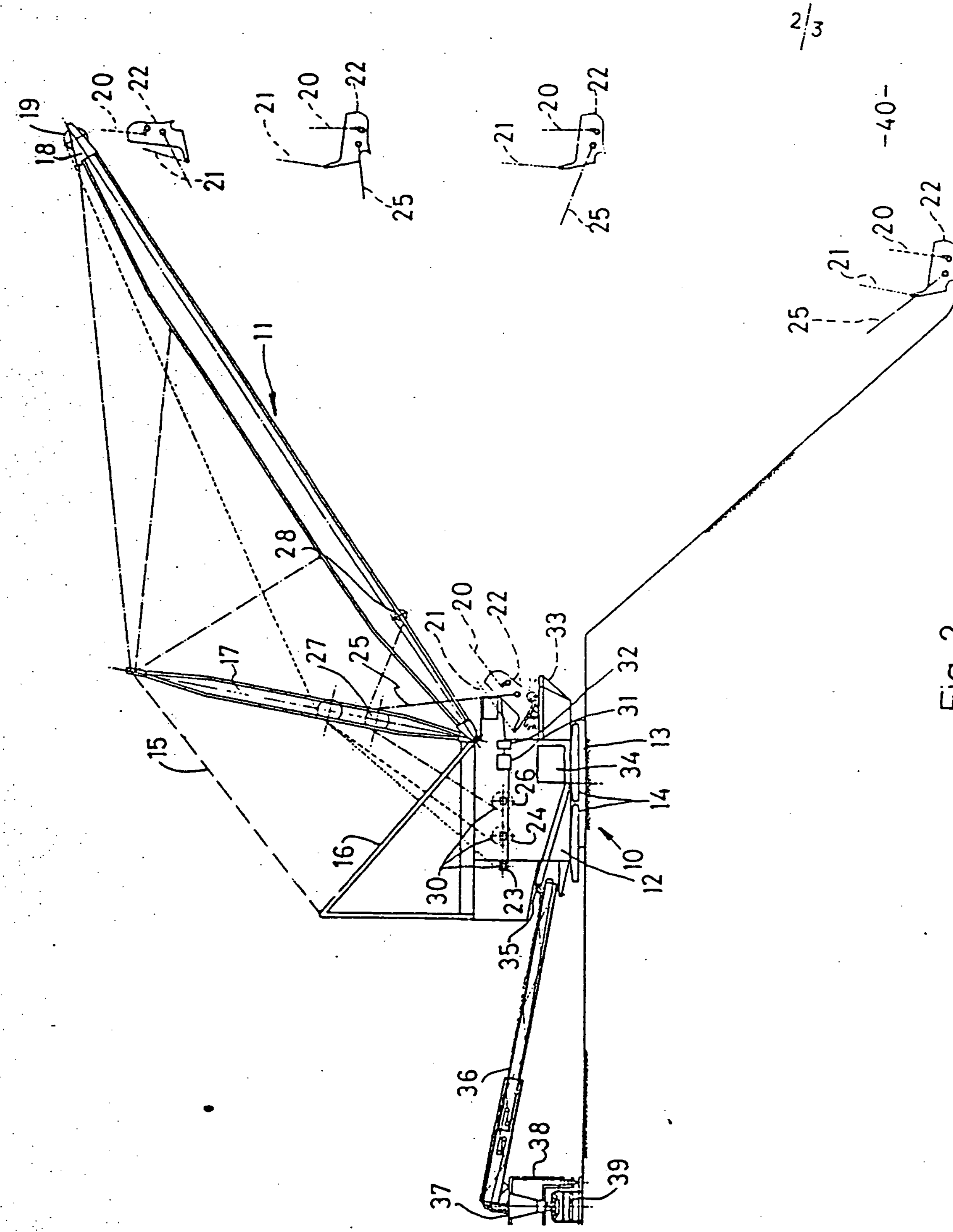
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Fig. 2.

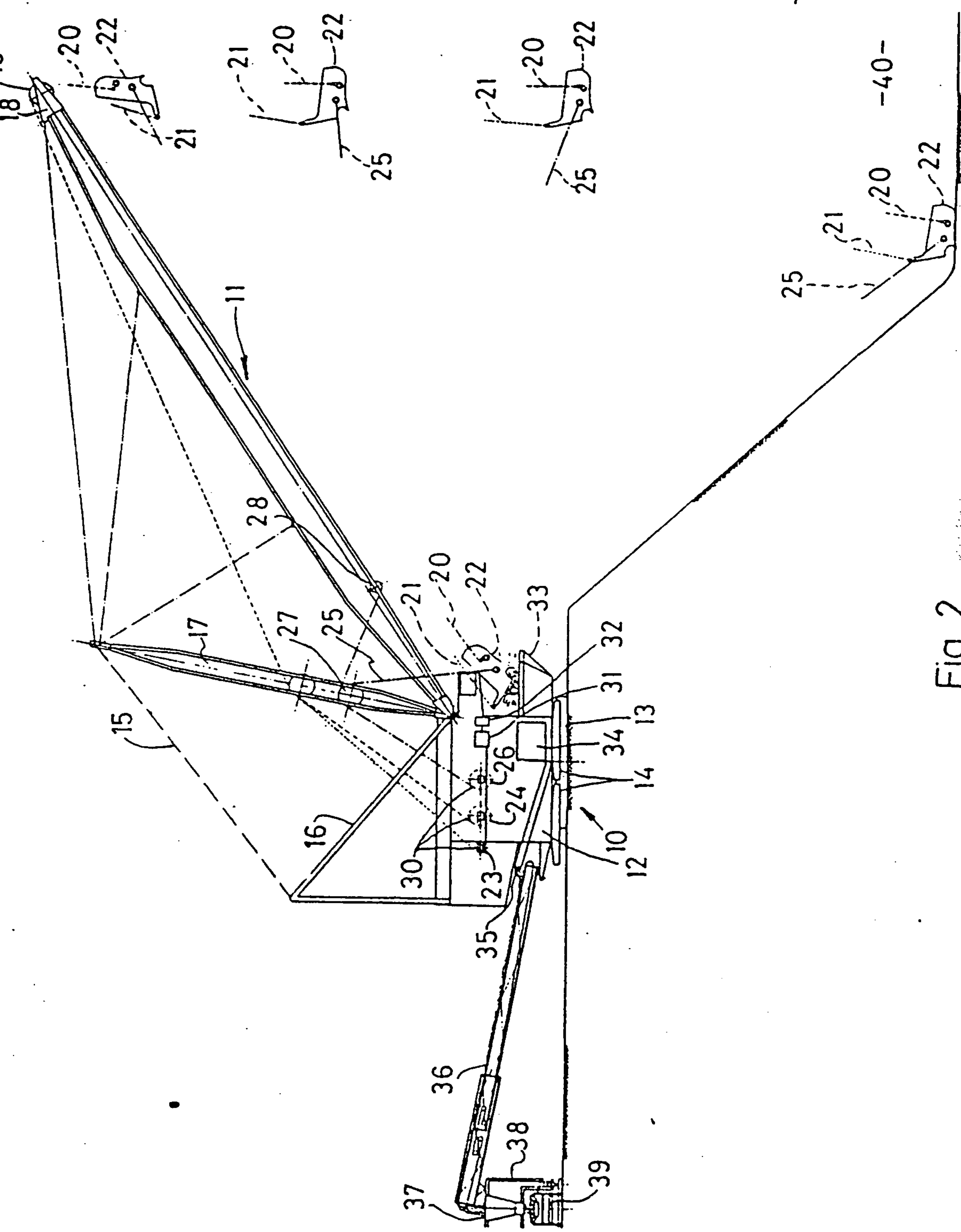
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Fig. 2

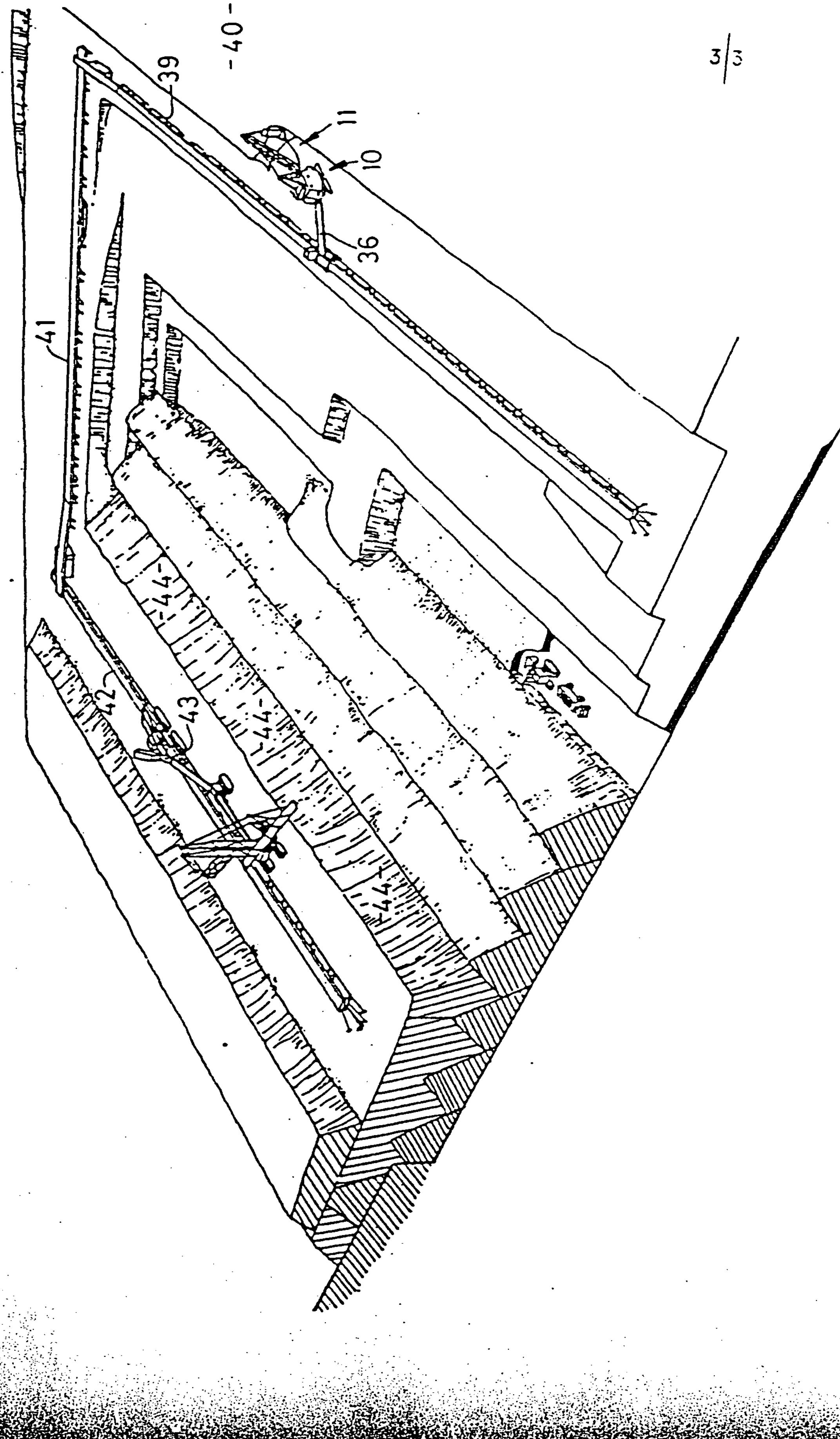

Fig. 3.

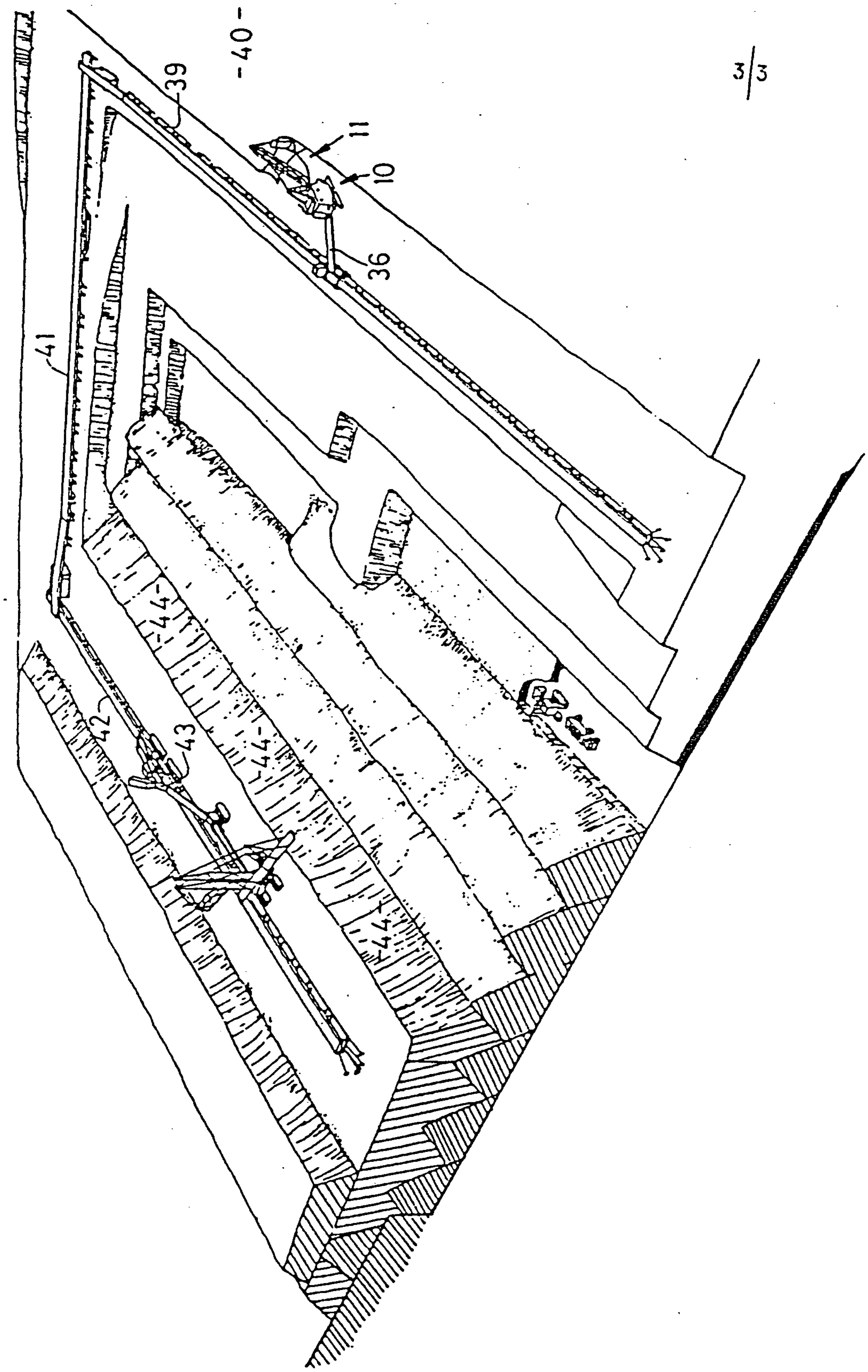

Fig. 3.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU84/00064

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3] E02F 3/48, E21C 47/00, 41/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	E02F 3/48, E21C 47/00, 41/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

AU: IPC as above; Australian Classification 84.31

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X,Y	AU, B, 38089/78 (502973) (MITSUBISHI MINING & CEMENT CO., LTD.) 16 August 1979 (16.08.79)	(1-3, 7-10 13, 17)
X,Y	AU, B, 39915/78 (501008) (MITSUBISHI MINING & CEMENT CO., LTD.) 7 June 1979 (07.06.79)	(1-10, 12-17)
X	SU, A, 195077 (TKACHENKO) 16 June 1967 (16.06.67) (Derwent English Language Abstract)	(1,8,9)

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
19 June 1984 (19.06.84)	(25-06-84) 25 JUNE 1984
International Searching Authority [1]	**Signature of Authorized Officer** [10]
Australian Patent Office	A.S. MOORE A. A. Moore

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/AU 84/00064

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
39915/78	CA 1098086	JP 55007319	US 4256342
38089/78	CA 1090280 US 4353796	JP 54023001	US 4261119

END OF ANNEX